

Reply to Tosh et al.: Quantitative analyses of cultural evolution require engagement with historical and archaeological research

Thomas E. Currie^c, Peter Turchin^{a,b}, Harvey Whitehouse^{d,e}, Pieter François^{d,f}, Kevin Feeney^g, Daniel Mullins^{d,h}, Daniel Hoyerⁱ, Christina Collins^c, Stephanie Grohmann^d, Patrick Savage^d, Gavin Mendel-Gleason^g, Edward Turnerⁱ, Agathe Dupeyronⁱ, Enrico Cioniⁱ, Jenny Reddishⁱ, Jill Levineⁱ, Greine Jordaniⁱ, Eva Brandl^{i,j}, Alice Williams^c, Rudolf Cesaretti^k, Marta Kruegerⁱ, Alessandro Ceccarelli^m, Joe Figliulo-Rosswurmⁿ, Po-Ju Tuaniⁱ, Peter Peregrine^{o,p}, Arkadiusz Marciniakiⁱ, Johannes Preiser-Kapeller^q, Nikolay Kradin^r, Andrey Korotayev^s, Alessio Palmisano^t, David Baker^u, Julye Bidmead^v, Peter Bol^w, David Christian^u, Connie Cook^{x,y}, Alan Covey^z, Gary Feinman^{aa}, Árni Daniél Júlíusson^{bb}, Axel Kristinsson^{cc}, John Miksic^{dd}, Ruth Mostern^{ee}, Cameron Petrie^{m,ff}, Peter Rudiak-Gould^{gg}, Barend ter Haar^{hh}, Vesna Wallace^v, Victor Mairⁱⁱ, Liye Xie^{jj}, John Baines^{kk}, Elizabeth Bridges^{ll}, Joseph Manning^{mm}, Bruce Lockhartⁿⁿ, Amy Bogaard^{oo}, and Charles Spencer^{pp}

^aDepartment of Ecology and Evolutionary Biology, University of Connecticut, CT 06269; ^bComplexity Science Hub Vienna, 1080 Wien, Austria; ^cHuman Behaviour & Cultural Evolution Group, Department of Biosciences, University of Exeter, Cornwall TR10 9FE, United Kingdom; ^dInstitute of Cognitive and Evolutionary Anthropology, University of Oxford, Oxford OX2 6PE, United Kingdom; ^eMagdalen College, Oxford OX1 4AU, United Kingdom; ^fSt. Benet's Hall, Oxford OX1 3LN, United Kingdom; ^gSchool of Computer Science and Statistics, Trinity College Dublin, Dublin 2, Ireland; ^hInstitute of English Studies, University of London, London WC1E 7HU, United Kingdom; ⁱSeshat: Global History Databank, Evolution Institute, San Antonio, FL 33576; ^jDepartment of Anthropology, University College London, London WC1H 0BW, United Kingdom; ^kSchool of Human Evolution and Social Change, Arizona State University, Tempe, AZ 85287; ^lInstitute of Archaeology, Adam Mickiewicz University, 61-614 Poznań, Poland; ^mDepartment of Archaeology, University of Cambridge, Cambridge CB2 3DZ, United Kingdom; ⁿDepartment of History, University of California Santa Barbara, Santa Barbara, CA 93106; ^oAnthropology and Museum Studies, Lawrence University, Appleton, WI 54911; ^pSanta Fe Institute, Santa Fe, NM 87501; ^qDivision for Byzantine Research, Institute for Medieval Research, Austrian Academy of Sciences, 1020 Wien, Austria; ^rDepartment of Anthropology, Institute of History, Archaeology and Ethnology, Far Eastern Branch of the Russian Academy of Sciences, Vladivostok 690001, Russia; ^sLaboratory of Monitoring of Destabilization Risks, National Research University Higher School of Economics, Moscow 125267, Russia; ^tInstitute of Archaeology, University College London, London WC1H 0PY, United Kingdom; ^uBig History Institute, Macquarie University, Sydney NSW 2109, Australia; ^vDepartment of Religious Studies, Chapman University, Orange, CA 92866; ^wEast Asian Languages and Civilizations, Harvard University, Cambridge, MA 02138; ^xDepartment of Modern Languages & Literatures, Lehigh University, Bethlehem, PA 18015; ^ySchool of Historical Studies, Institute of Advanced Studies, Princeton, NJ 08540; ^zDepartment of Anthropology, University of Texas Austin, Austin, TX 78712; ^{aa}Integrative Research Center, Field Museum of Natural History, Chicago, IL 60605; ^{bb}History, University of Iceland, IS-108 Reykjavik, Iceland; ^{cc}History, Reykjavik Academy, IS-108 Reykjavik, Iceland; ^{dd}Department of Southeast Asian Studies, National University of Singapore, Singapore 119260; ^{ee}Department of History, University of Pittsburgh, Pittsburgh, PA 15260; ^{ff}Trinity College, Cambridge CB2 1TQ, United Kingdom; ^{gg}Independent Scholar, Toronto, ON M6P 1T6, Canada; ^{hh}Faculty of Oriental Studies, University of Oxford, Oxford OX2 6LU, United Kingdom; ⁱⁱDepartment of East Asian Languages and Civilizations, University of Pennsylvania, Philadelphia, PA 19104; ^{jj}Department of Anthropology, University of Toronto, Toronto, ON M5S 2S2, Canada; ^{kk}Faculty of Oriental Studies, Oriental Institute, University of Oxford, Oxford OX1 2LE, United Kingdom; ^{ll}Institute of Archaeology and Anthropology, University of South Carolina, Columbia, SC 29208; ^{mm}Department of History, Yale University, New Haven, CT 06520; ⁿⁿDepartment of History, National University of Singapore, Singapore 117570; ^{oo}Institute of Archaeology, University of Oxford, Oxford OX1 2PG, United Kingdom; and ^{pp}Division of Anthropology, American Museum of Natural History, New York, NY 10024

We thank Tosh et al. (1) for their interest in our research (2), but note that their analyses do not undermine the main findings of our article. Their suggestion that polity population divided by polity area should be one of the social complexity dimensions raises a number of issues. What does this ratio mean at large spatial scales, where populations are concentrated in large urban centres and much of the territory is not heavily populated? How are societies distributed across this variable and why? - a small-scale “simple” society could have very

high population density if they have access to rich resource density. Tosh et al. do not provide sufficient information or context to meaningfully interpret their results.

The study by Chick (3), cited by Tosh et al., was based on the SCCS, which is heavily weighted towards low-complexity small-scale societies. The second component that Chick found captures the differences in mobility and mode of production between agricultural and foraging societies, rather than complexity of organization *per se*. Tosh et al. also argue without evidence that the proportion of variance explained by PC2 “would likely have been higher had Turchin et al.’s data also allowed us to reconstruct agricultural intensity and urbanization.” In fact, our variable “capital population” is a proxy for urbanization, i.e. more urbanized societies would have larger population centers. Agricultural intensity (if interpreted as agricultural productivity rather than whether agriculture is practiced) is likely to be strongly correlated with the complexity variables that we included in our study (4).

Finally, Tosh et al. question our use of multiple imputation to deal with missing data. The number of counter-intuitive cases produced appears low and we already demonstrated that our results were robust with respect to the multiple imputation procedure and the degree of missing data. These techniques can always be improved, but we strongly disagree with Tosh et al.’s suggestion that it would be “wiser for researchers to estimate intervals manually.” A major guiding principle of the Seshat project is to reflect not only what is known, but also what is unknown, by which we mean that experts do not have sufficient information to enter a value. Entering values manually based on guesses risks introducing unexplored assumptions and serious biases. Our paper is the product of a deep engagement between scientists and humanities scholars across a number of disciplines (5, 6). We aim to capture information across large expanses of space and time in a systematic but thoughtful way that is sensitive to the challenges of the historical and archaeological records.

We fully recognize that in a study of this magnitude there will inevitably be inconsistencies, disagreements, and the need to modify or update the databank as new information becomes available. We have created a website (<http://seshatdatabank.info/data/>) to enable all to view our data and see the reasons behind coding decisions. We invite experts on past societies to use this web resource to make suggestions as to where data can be improved or added.

1. Tosh N, Ferguson J, & Seoighe C (2018) History by the numbers?
2. Turchin P, *et al.* (2018) Quantitative historical analysis uncovers a single dimension of complexity that structures global variation in human social organization. *Proceedings of the National Academy of Sciences* 115(2):E144-E151.
3. Chick G (1997) Cultural Complexity: The Concept and Its Measurement. *Cross-Cultural Research* 31(4):275-307.
4. Currie TE, *et al.* (2015) Agricultural productivity in past societies: Toward an empirically informed model for testing cultural evolutionary hypotheses. *Cliodynamics: The Journal of Quantitative History and Cultural Evolution* 6(1).

5. Francois P, *et al.* (2016) A Macroscope for Global History: Seshat Global History Databank, a methodological overview. *Digital Humanities Quarterly*.
6. Turchin P, *et al.* (2015) Seshat: The Global History Databank. *Cliodynamics: The Journal of Quantitative History and Cultural Evolution* 6(1).